Draft Total Maximum Daily Load for Dissolved Oxygen/Organic Enrichment/Nutrients

Flint Creek Watershed

November 5, 2001

EPA
United States
Environmental Protection
Agency

Region 4
serving the southeast

1.0 Executive Summary

This report presents Total Maximum Daily Loads (TMDLs) for 9 waterbody segments found on Alabama's 1996 Section 303(d) List of Impaired Waterbodies within the Flint Creek Watershed. Of these segments, all nine are listed as impaired for organic enrichment (OE) and low dissolved oxygen (DO). One of the nine, the main stem of Flint Creek, is also listed as impaired for nutrients. Table 1-1 presents the listed segment names along with ID numbers, the designated uses, the causes of impairment, the sources of impairment and the lengths of impairment. Figure 1-1 presents a map of the Flint Creek Watershed with the listed segments identified along with their designated use.

Waterbody Name (ID)	Designated Uses*	Causes of Impairment	Sources of Impairment	Segment Length (mi)
Flint Creek (06030002-330_01)	F&W + PWS + A&I	OE/DO Nutrients	Municipal Point Sources Nonirrigated Crop prod. Pasture Grazing Int.Animal Feeding Oper. Urban runoff/Storm Sewers	40.0
Shoal Creek ((06030002-330_02)	F&W	OE/DO	Urban runoff/storm sewers	10.9
Town Branch (06030002-330_03)	F&W	OE/DO	Urban runoff/storm sewers	1.9
Mack Creek (06030002-330_03)	F&W	OE/DO	Pasture Grazing	5.4
Robinson Creek (06030002-330_05)	F&W	OE/DO	Agriculture	6.3
Crowdabout Creek (06030002-340_01)	F&W	OE/DO	Nonirrigated Crop Prod. Pasture Grazing Int. Animal Feeding Oper.	15.0
No Business Creek (06030002-350_02)	F&W	OE/DO	Nonirrigated Crop Prod. Pasture Grazing	6.3
Village Branch (06030002-350_03)	F&W	OE/DO	Agriculture	5.7
McDaniel Creek (06030002-360_02)	F&W	OE/DO	Agriculture	3.9

Table 1-1. 303(d) Listed Segments within the Flint Creek Watershed

Within the Flint Creek watershed three designated uses exist, Fish and Wildlife (F&W), Public Water Supply (PWS), and Limited Warmwater Fishery (LWF). In accordance with ADEM water quality standards, the minimum dissolved oxygen concentration in a stream classified as F&W or PWS is 5.0 mg/l except in extreme conditions due to natural causes where DO levels will not drop below 4.0 mg/L. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be allowed in those areas listed as F&W or PWS except under extreme low flow conditions where a 4.0 mg/L standard will be applied. The minimum dissolved oxygen concentration in a stream classified as LWF is 3.0 mg/L from May through November. At all other times the dissolved oxygen shall not be below 5.0 mg/L.

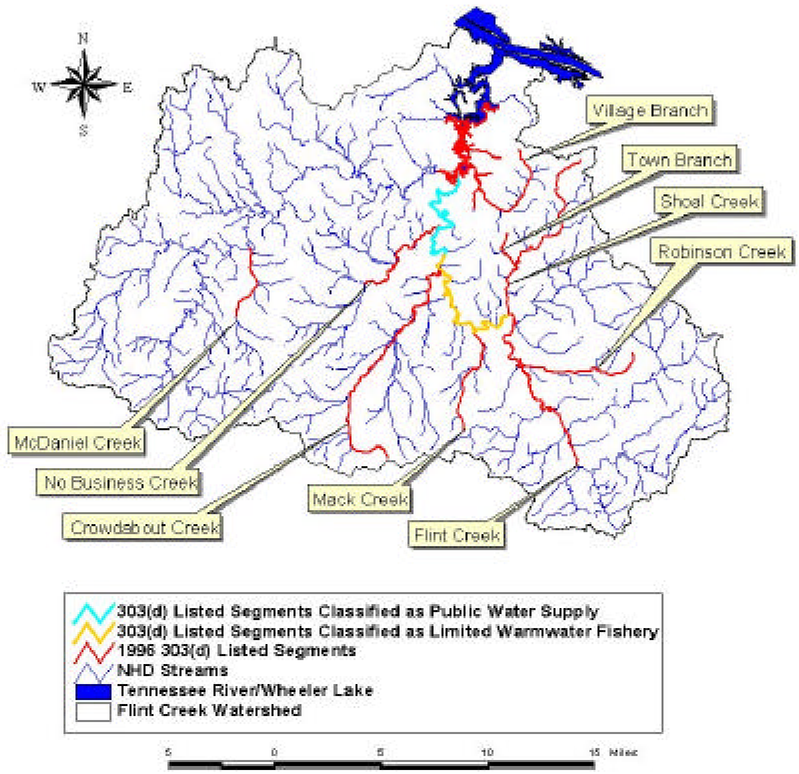

Figure 1-1. 303(d) Listed Reaches within the Flint Creek Watershed with Associated Use Classification

A summary of the TMDL for the watershed is provided in Table 1-2. The pollutants shown in the table for all nine listed segments include ultimate carbonaceous biochemical oxygen demand ($CBOD_u$) and nitrogenous biochemical oxygen demand ($NBOD_u$), total nitrogen (TN) and total phosphorus (TP). $CBOD_u$ and $NBOD_u$ are the principle causes for observed low dissolved oxygen concentrations. $CBOD_u$ is a measure of the total amount of oxygen required to degrade the carbonaceous portion of the organic matter present in the water. $NBOD_u$ is the amount of oxygen utilized by bacteria as they convert ammonia to nitrate. Because organic nitrogen can be converted to ammonia, its potential oxygen demand is included in the $NBOD_u$ component of the TMDL. The first table lists allowable pollutant loadings by source (point and non-point sources) for the summer season (May through November), the second table presents the percent reductions required in each watershed to achieve those levels for the nonpoint sources. Compliance under extreme summer low flow conditions assures that standards are met throughout the year.

The wasteload allocations (WLA) within the system represent the contributions from the point source discharges. Under this TMDL it was determined that the point source discharges are not a significant portion of the loading to the system and no reductions were identified to meet water quality targets. The WLA therefore will reflect current permit limits.

For the load allocation to the nonpoint sources (LA), the impacts are associated with increased levels of organic material in the benthic layers and a resulting increased sediment oxygen demand under low flow conditions. The allocation to the nonpoint sources therefore represents reductions necessary to reduce long-term sediment oxygen demand within the system to meet water quality standards for dissolved oxygen. In this case the determination of the nonpoint source loads represents long-term annual average loadings.

This document presents a summary of the data analysis and model work performed in the development of the TMDL. Details of model development, calibration, and TMDL scenario applications are presented in a draft report entitled "Development of a system of models for evaluation of dissolved oxygen and organic enrichment TMDLs in the Flint Creek Watershed." This report is herein after referred to as the Draft Modeling Report.

Listed Reach	CBODU (lb/year)	NBODU (lb/year)	TN (lb/year)	TP (lb/year)
Crowdabout Creek	554602	74851	273767	32062
Flint Creek	6230667	870754	2712181	327794
Mack Creek	101308	11924	48293	6346
McDaniel Creek	181077	31916	79354	8390
No Business Creek	374884	54561	188956	20562
Robinson Creek	121958	14357	58144	7640
Shoal Creek	344865	33018	103539	13099
Town Branch	68608	3832	9599	1211
Village Branch	174060	19469	75015	9801

Listed Reach	CBODU (% Reduction)	NBODU (% Reduction)	TN (% Reduction)	TP (% Reduction)
Crowdabout Creek	41%	52%	21%	18%
Flint Creek	38%	47%	16%	11%
Mack Creek	39%	56%	24%	19%
McDaniel Creek	28%	36%	17%	15%
No Business Creek	44%	62%	30%	24%
Robinson Creek	53%	49%	15%	12%
Shoal Creek	49%	39%	13%	6%
Town Branch	62%	48%	2%	0%
Village Branch	30%	19%	4%	2%

Table 1-2. TMDL Loads and Percent Reductions by Listed Segment and Pollutant for the Nonpoint Source Contributions

2.0 Basis for §303(d) Listing

2.1 Introduction

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987 and EPA's Water Quality Planning and Management Regulations [(Title 40 of the Code of Federal Regulations (CFR), Part 130)] require states to identify waterbodies which are not meeting water quality standards applicable to their designated use classifications. The identified waters are prioritized based on severity of pollution with respect to designated use classifications. Total maximum daily loads (TMDLs) for all pollutants causing violation of applicable water quality standards are established for each identified water. Such loads are established at levels necessary to implement the applicable water quality standards with seasonal variations and margins of safety. The TMDL process establishes the allowable loading of pollutants, or other quantifiable parameters for a waterbody, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Alabama has identified 9 segments within the Flint Creek Watershed as being impaired by organic loading (i.e., $CBOD_u$ and $NBOD_u$) with one of the nine segments additionally listed as impaired for nutrients. The listings are reported on the 1996 §303(d) list(s) of impaired waters.

The TMDLs developed for the Flint Creek Watershed illustrate the steps that can be taken to address a waterbody impaired by low dissolved oxygen levels and nutrients where nonpoint source loads are the primary cause of impairment. The TMDL is consistent with a phased-approach: estimates are made of needed pollutant reductions, load reduction controls are implemented, and water quality is monitored for plan effectiveness. Flexibility is built into the plan so that load reduction targets and control actions can be reviewed and updated if monitoring indicates continuing water quality problems.

2.2 Problem Definition

The Flint Creek Watershed is located within the Tennessee River Basin with the tailwaters of Flint Creek discharging directly to the backwater area of Wheeler Lake, a reservoir along the Tennessee River. Figure 2-1 presents the location of the Flint Creek Watershed within the State of Alabama and the Tennessee River Basin. The Flint Creek watershed covers a total of 453 square miles in parts of Cullman, Lawrence, and Morgan Counties. Most of the surface waters within the Flint Creek Watershed are classified Fish and Wildlife (F&W), however, the lower part of Flint Creek is also classified Public Water Supply (PWS), and a 9-mile long central part is classified Limited Warmwater Fishery (LWF).

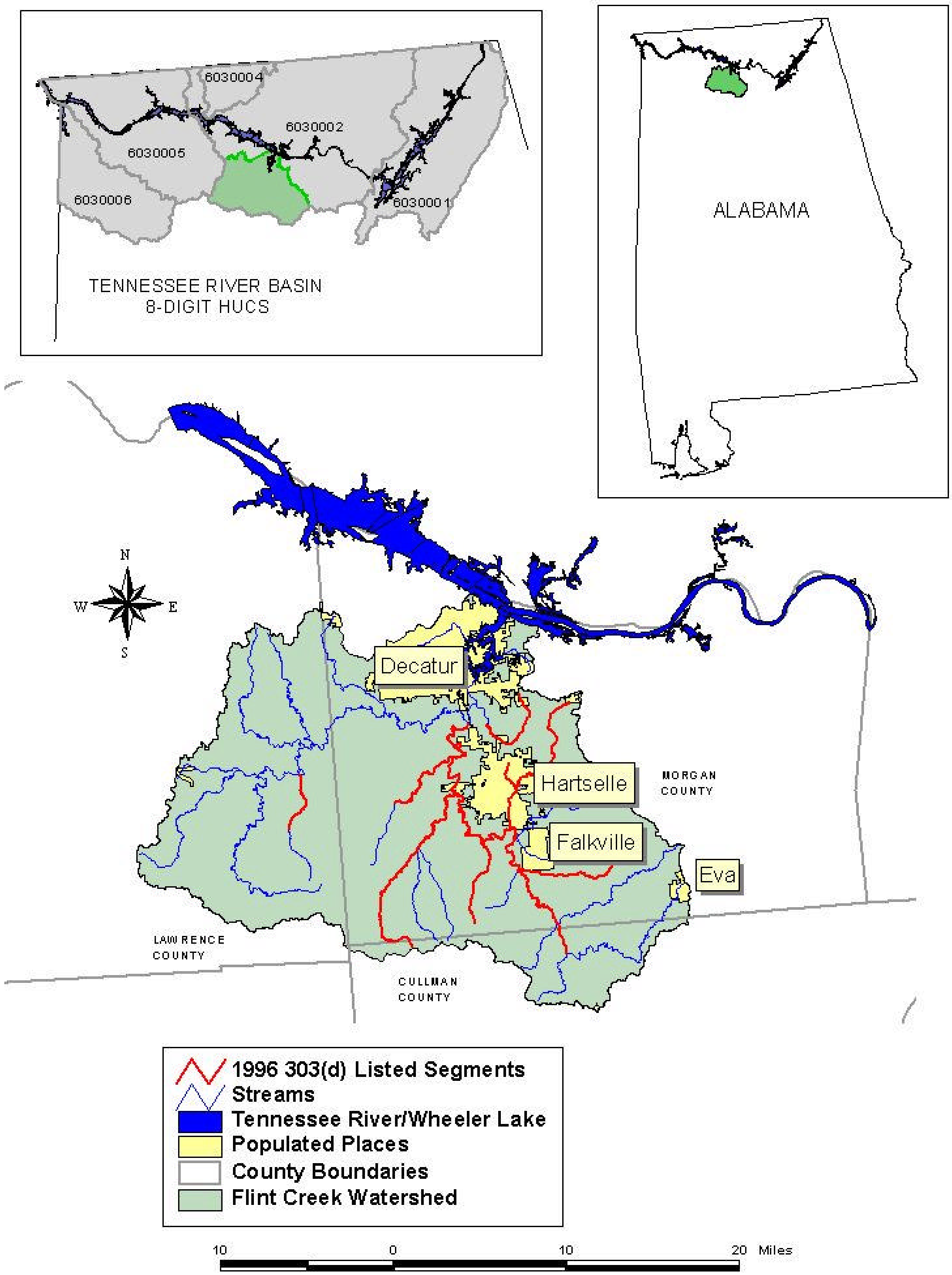

Figure 2-1. Location Map for the Flint Creek Watershed

The overall surface water quality within the Flint Creek Watershed is fair to poor. Biological assessments have indicated areas of poor fish health (ADEM, 1996a) with polluted surface water runoff from agricultural land uses a significant problem. Major land uses that impact water quality are agricultural areas within the watershed as well as urban areas around the City of Hartselle. Figure 2-2 presents the USGS Multi-Resolution Landuse Classification (MLRC) dataset for the Flint Creek Watershed. The dominance of agricultural activity within the watershed can be seen with 40 percent of the watershed landuse as agriculture.

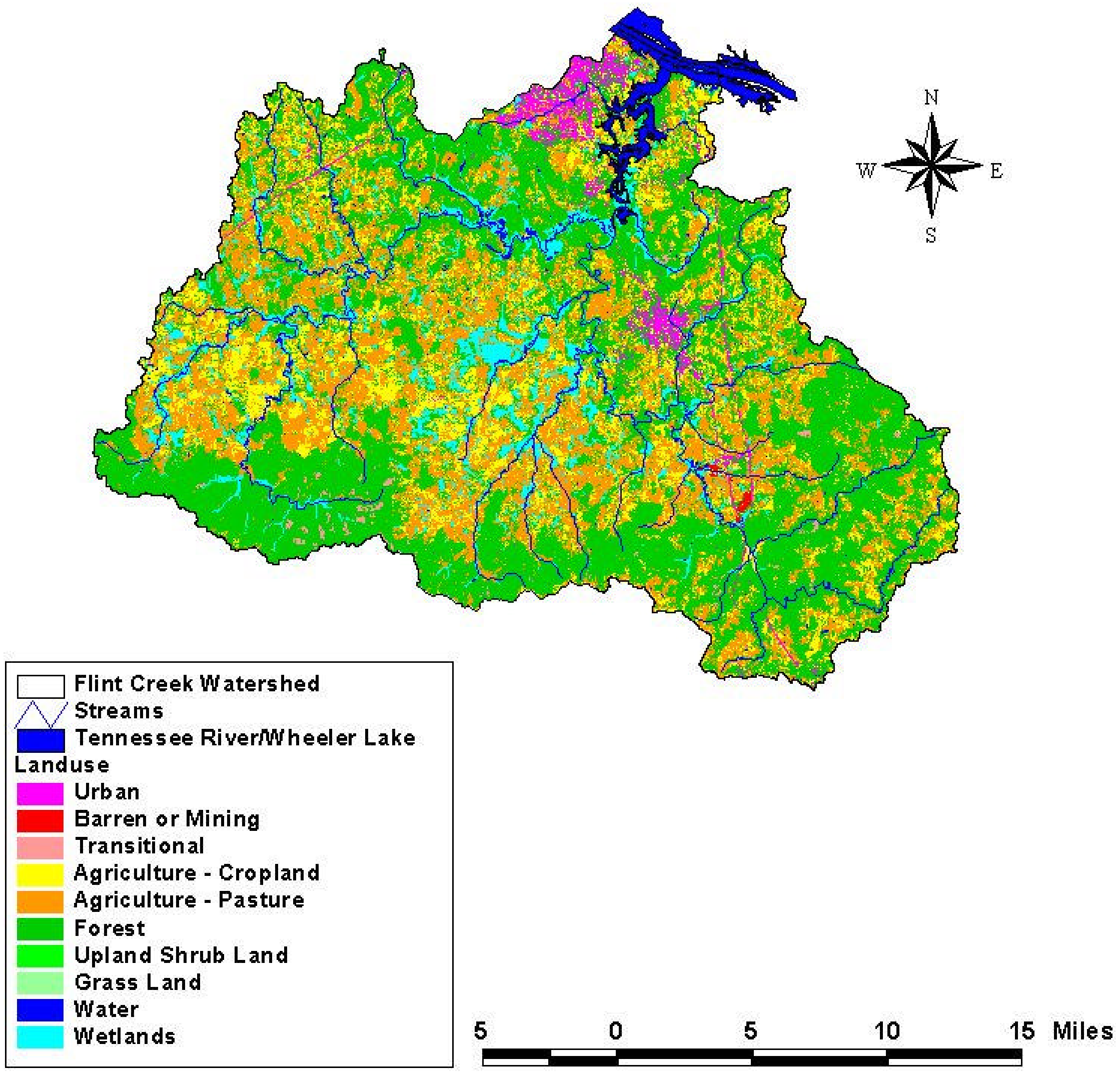

Figure 2-2. Land Use Representation in the Flint Creek Watershed

Water quality monitoring conducted from 1993 through 1998, and presented in detail in Section 3.4, indicated periods of time within the watershed where dissolved oxygen conditions dropped well below the State standard of 5.0 mg/L. These conditions occur during the critical summer months under low flow conditions.

Hydrologic conditions that affect surface-water quality include the backwater impacts of Wheeler Lake in lower Flint Creek and West Flint Creek and the high variability in streamflow, producing extreme low flows in summer-fall (Chandler, 1999). Backwater of Wheeler Lake is important at times of low flow because it promotes accumulation of organics, algae (duckweed) growth and low dissolved oxygen levels, reduces stream aeration potential, and increases biochemical and sediment oxygen demands of water in the lower parts of the Flint Creek Watershed. Management practices within Wheeler Lake create a typical seasonal pattern in water surface elevation that rises in late spring and summer up to an elevation of 556 feet down to 550 feet during late Fall and Winter. Figure 2-3 presents the extent of backwater area within the Flint Creek Watershed under low flow conditions with the surface elevation range from 550 to 556 feet.

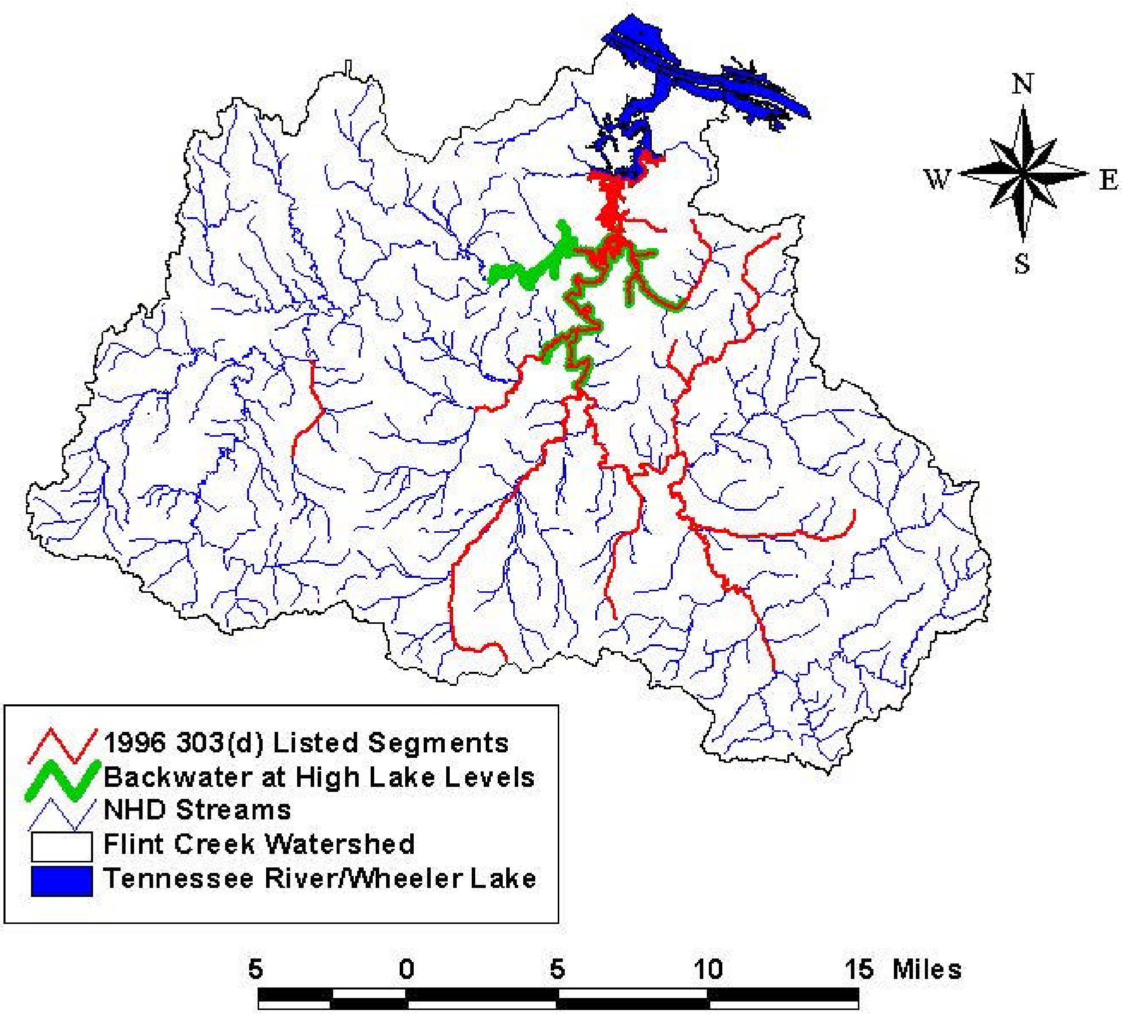

Figure 2-3. Extent of Backwater in Flint Creek and West Flint Creek

The purpose of this TMDL is to establish the acceptable loading of nutrients and organic material from all sources, such that the water quality criteria for dissolved oxygen is not violated.

<u>Water Quality Criterion Violation:</u> Dissolved Oxygen

<u>Pollutant of Concern:</u> Organics and Nutrients

<u>Water Use Classification (multiple):</u> F&W, PWS, LWF

Eight of the impaired segments, along with all but approximately 20 miles of Flint Creek are classified as **Fish and Wildlife** (F&W). Usage of waters in this classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

Alabama's water quality criteria document (ADEM Admin. Code R. 335-6-10-.09-(5)(e)(4.)) states that for a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels.

9 miles of the Flint Creek, river mile 11.4 to 20.4, is classified as **Public Water Supply**. Usage of waters in this classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

Alabama's water quality criteria document (ADEM Admin. Code R. 335-6-10-.09-(5)(e)(4.)) states that for a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times; except under extreme conditions due to natural causes, it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels.

10.2 miles of the Flint Creek, river mile 20.4 to 30.6, is classified as **Limited Warmwater Fishery**. Usage of waters in this classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b), (c), and (d).

Sewage, industrial wastes, or other wastes shall not cause the dissolved oxygen to be less than 3.0 mg/L (May through November).

3.0 Technical Basis for TMDL Development

3.1 Water Quality Target Identification

The minimum dissolved oxygen concentration in a stream classified as Fish and Wildlife (or Public Water Supply) is 5.0 mg/l, except under extreme natural conditions where a 4.0 mg/L will be allowed. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be implemented during normal periods while a 4.0 mg/l will be implemented under extreme low flow conditions within waters classified as F&W or PWS. The minimum dissolved oxygen concentration in a stream classified as Limited Warmwater Fishing is 3.0 mg/l for the months from May through November. The water quality target for this TMDL will have a spatially varient component, where certain reaches of the Flint Creek (see Figure 1-1) will allow for a minimum of 3.0 mg/L. In order to account for daily fluctuations in the dissolved oxygen concentrations using a daily average model prediction, an additional 0.5 mg/L factor will be added to the target to account for the diurnal fluctuations and assure that criteria are met at all time. The target $CBOD_{u,,}$ $NBOD_u$, Total Nitrogen and Total Phosphorus concentrations, will not deplete the daily dissolved oxygen concentration below this level as a result of the decaying process.

3.2 Source Assessment

3.2.1. General Sources of CBODu, NBOD, Nitrogen and Phosphorus

Both point and non-point sources may contribute $CBOD_{u,}$ $NBOD_u$ and Nutrients to a given waterbody. Potential sources of organic loading are numerous and often occur in combination. In rural areas, storm runoff from row crops, livestock pastures, animal waste application sites, and feedlots can transport significant loads of organic material. Nationwide, poorly treated municipal sewage comprises a major source of organic compounds that are hydrolyzed to create additional organic loading. Urban storm water runoff, sanitary sewer overflows, and combined sewer overflows can be significant sources of organic loading.

All potential sources of organic loading in the watershed were identified based on an evaluation of current land use/cover information on watershed activities (e.g., agricultural management activities). The source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations. The organic and nutrient loading within the watershed included both point and non-point sources.

3.2.2. Point Sources in the Flint Creek Watershed

ADEM maintains a database of current NPDES permits and GIS files that locate each permitted outfall. This database includes municipal, semi-public/private, industrial, mining, industrial storm water, and concentrated animal feeding operations (CAFOs) permits. Table 3-1, below, shows the permitted point sources in the watershed that discharge into the Flint Creek watershed. Table 3-2 contains the permit limitations for the significant point sources that were considered in the model development. Figure 3-1 shows the location of each facility considered a significant source relative to the impaired segment.

NPDES Permit Number	Type of Facility	Facility Name	Significant Contributor (Y/N)
AL0054674	Municipal	Hartselle	Y
AL0021113	Municipal	Falkville	Y
AL0059552	Semi-public/private	Ala Sheriffs Boys Ranch	N
AL0051870	Semi-public/private	Danville High School	N
AL0051888	Semi-public/private	Priceville School	N
AL0043028	Semi-public/private	Speake Schools	N
AL0054870	Semi-public/private	E. Lawrence Schools	N
AL0051128	Semi-public/private	Vinemont School	N

Table 3-1. NPDES Permitted Discharges in the Flint Creek Watershed

<u>Note</u>: Storm water discharges listed in the above table were marked as not being significant contributors since the discharge would not occur during low flow conditions. Construction storm water discharges are not listed as these discharges do not occur during low flow and generally do not contribute directly to the organic loading.

Facility Name	Permit Limitations Summer (May-Nov.)							Permit Limitations Winter (Dec.-Apr.)						
	Flow (MGD)		BOD5 (mg/L)		NH3 (mg/L)		DO	Flow (MGD)		BOD5 (mg/L)		NH3 (mg/L)		DO
	Max	Ave	Max	Ave	Max	Ave	Min	Max	Ave	Max	Ave	Max	Ave	Min
Hartselle		2.7000		8		1	7		2.7		30		2.5	7
Falkville		0.2700		30		NL	NL		0.2700		30		NL	NL
Ala Sheriffs Boys Ranch		0.0130		4		1.2	5		0.0130		7		1.2	5
Danville High School		0.0260		5		1	5		0.0260		25		1	5
Priceville School		0.0270		inactive		inactive	inactive		0.0270		inactive		inactive	inactive
Speake Schools		0.0175		10		1.2	6		0.0175		30		1.2	6
E. Lawrence Schools		0.0250		10		1.2	5		0.0250		25		1.2	5
Vinemont School		0.0250		25		1.4	6		0.0250		25		1.4	6

Permitted flow is "Design Flow"
Permit limits are confirmed as average.

Table 3-2. Permit Limits for Significant Discharges

Flows listed for municipal and industrial permits are design flow and long term average flows, respectively. The flows listed for industrial permits may or may not be limited by the permit, but are included for the purpose of calculating the percent of the $7Q_{10}$.

The two significant point sources within the Flint Creek Watershed relative to dissolved oxygen impairments are the Faulkville and Hartselle discharges. The Hartselle municipal wastewater treatment facility, operating under NPDES permit AL0054674, is the largest point source in the Flint Creek watershed, discharging into Shoal Creek approximately 0.45 mile from the confluence with Flint Creek. According to plant engineer Wayne Roberson, in times of drought, the plant discharge comprises the majority of the streamflow in Shoal Creek. Hartselle is permitted to discharge an average of 2.7 MGD with different permit limits for BOD and ammonia in summer (May-November) and winter (December-April). The discharge limits for permitted point sources in the watershed are listed in Table 3-2. According to monthly average discharge monitoring reports (DMRs), historical discharge has varied in the range from 0.79 to 4.84 MGD in the years 1993-April 2001, with a median monthly average discharge of 1.88 MGD.

The Falkville 275,000 gallon municipal wastewater lagoon, operating under NPDES permit AL0021113, discharges directly to Flint Creek with a permitted flow defined by the regression equation:

Discharge (MGD) = [0.0857 x Streamflow (CFS)] – 2.143

Streamflow in Flint Creek must be at least 25 CFS for Falkville to discharge. According to Chris Lovelace of the Town of Falkville, the lagoon has "very good evaporation" and only 385 customers, so that the lagoon requires only one or two discharges annually. The most recent discharge was on October 5, 2001, a small release to allow a sample to be taken for the permit renewal process. The sample contained a BOD5 concentration of 38.3 mg/l and 6.38 mg/l ammonia.

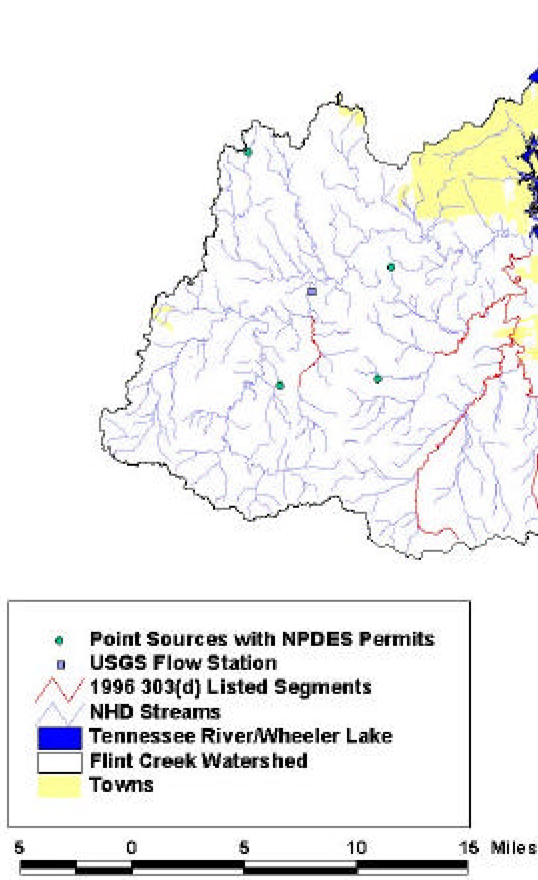

Figure 3-1. Significant Point Source Discharges in the Flint Creek Watershed

3.2.3. Non-Point Sources in the Flint Creek Watershed

Shown in Table 3-3, is a detailed summary of land usage in the Flint Creek watershed. A land use map of the watershed is presented in Figure 2-2. Figure 3-2 presents a pie chart depicting the principal land use distribution. The predominant land uses within the watershed are Forest and Agriculture. Their respective percentages of the total watershed are 46% and 40% respectively.

Landuse	Acres	Percentages
Urban	7545	2.5%
Barren/Mining	323	0.1%
Transitional	1154	0.4%
Agricultural - Cropland	41495	13.7%
Agricultural - Pasture	79765	26.3%
Forest	139423	46.0%
Water	4322	1.4%
Wetlands	21477	7.1%
Total	303049	100%

Table 3-3. Land Use Distribution

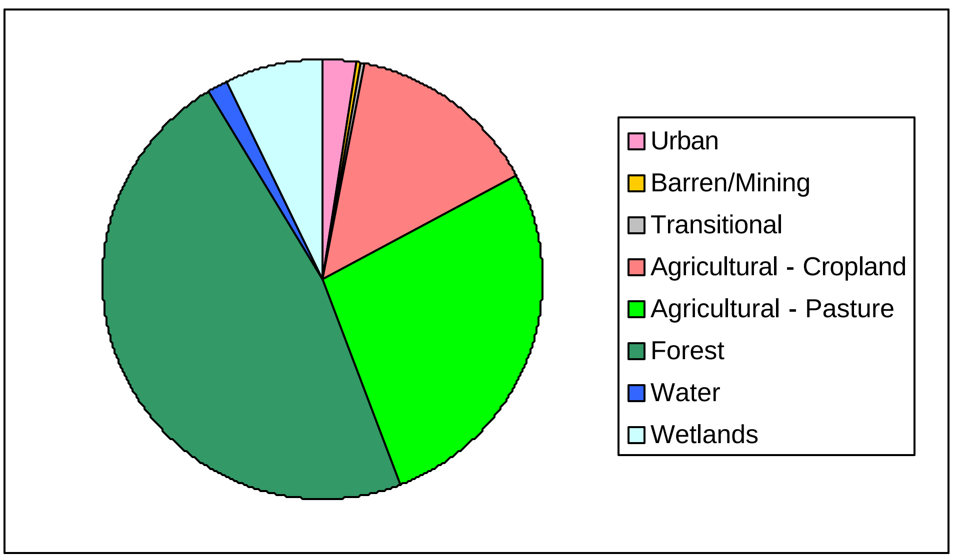

Figure 3-2. Land Use Distribution within Flint Creek Watershed

Each land use has the potential to contribute to the organic loading in the watershed due to organic material on the land surface that potentially can be washed off into the receiving waters of the watershed. Information on agricultural and management activities and watershed characteristics were obtained through coordination with the ADEM Mining and Non-Point Section, the Alabama Cooperative Extension System, and the USDA-Natural Resources Conservation Service (NRCS).

The major sources of organic enrichment from non-point sources within the Flint Creek watershed are the wash off of nutrients and organic material from agricultural lands and direct discharge to streams due to cattle. Another non-point source contribution would be leaking septic systems. Compared to other land uses, organic enrichment from forested land is normally considered to be small. This is because forested land tends to serve as a filter of pollution originating within its drainage areas. However, organic loading can originate from forested areas due to the presence of wild animals such as deer, raccoons, turkeys, waterfowl, etc. Control of these sources is usually limited to land management best management practices (BMPs) and may be impracticable in most cases. In contrast to forested land, agricultural land can be a major source of organic loading. Runoff from pastures, animal operations, improper land application of animal wastes, and animals with access to streams are all mechanisms that can introduce organic loading to water bodies. The following presents specific discussions of non-point source loads of organic material and nutrients considered in the model development.

Grazing Livestock

Agricultural runoff from cropland and pasture can often contribute increased organic enrichment and nutrient loads to a water body when poor farm management practices allow animal waste to be washed into the stream, increasing in-stream concentration levels.

Grazing cattle and other agricultural animals deposit manure and, therefore, organic material on the land surface, where it is available for washoff and delivery to receiving water bodies. Although specific information regarding agricultural management practices and activities are not readily available, ADEM keeps a database of agricultural and land use information provided by the various Soil and Water Conservation Districts throughout the state. The database is called the Soil and Water Conservation Assessment (SWCA) Database and contains information based on the 1997 Agricultural Census. Data from the SWCA database provided estimates of livestock in the Flint Creek watershed. Total pastureland and cropland within the watershed was provided by the MRLC land use coverage. The livestock counts and agricultural areas were used to determine livestock densities (e.g., number of cows, hogs, and chickens per acre of pasture land and/or cropland) for the watershed. The area of pastureland and cropland in each subwatershed was determined using GIS data layers. The pasture and cropland area of the subwatersheds and the livestock density for each subwatershed were used to calculate the livestock counts within each subwatershed. The number of chickens were split between cropland and pasture by area weighting and were distributed evenly over both land uses. Dairy cows were distributed evenly over pasture and hogs were distributed evenly over cropland.

The total livestock counts for the Flint Creek watershed are presented in Table 3-4. Livestock counts per subwatershed are presented in the Draft Modeling Report.

Beef Cattle	Dairy Cows	Hogs	Chickens
42,578	2,900	2,000	9,480,123

Source: Soil and Water Conservation Assessment Database

Table 3-4. Livestock Counts in the Flint Creek Watershed

Failing Septic Systems

Septic systems are common in unincorporated portions of the watershed and may be direct or indirect sources of nutrients and organic enrichment via ground and surface waters. A high percentage of the citizens in the Flint Creek watershed rely on septic systems for wastewater treatment (Bureau of the Census 2000). The information in the aforementioned SWCA database contains numbers and failure rates of septic systems in each of the four 11-digit HUCs in the Flint Creek watershed. Onsite septic systems have the potential to deliver loads to surface waters due to system failure and malfunction. To evaluate this loading, it is necessary to evaluate where septic tanks are located and what proportion of septics are malfunctioning.

The number of septic systems in the Flint Creek watershed were provided by ADEM, but the spatial distribution of septic tanks is not known. The density of septic systems (number per acre) was determined for each 11-digit HUC within the Flint Creek watershed based on the total number of septics provided within each HUC. It was assumed that septic systems are distributed evenly throughout the watershed. After estimating the number of septic systems per subwatershed, the number of failing systems per subwatershed were determined in order to calculate nutrient and organic material loading. The Draft Modeling Report presents the number of septic systems and the septic system failure rate assumed for each of the subwatersheds.

Cattle in the Stream

The SWCA Database provided information stating that livestock access to streams is a concern in the watershed. When cattle are not denied access to stream reaches, they represent a major potential source of direct loading. To account for the potential influence of loads deposited directly in stream reaches within the watersheds, nutrient and organic loads from cattle in streams were calculated and characterized as a direct source of loading to the stream segments. It was assumed that dairy cattle are mostly confined and that only beef cattle have access to streams. To determine the number of cows in the stream at any time, it was assumed that 10 percent of the cows in the watershed have access to streams; that 3 percent of those cows are in or around the stream at any given time; and that 1 percent of those cows in the stream are actually depositing manure in the stream reach at any given time.

3.3 Loading Capacity – Linking Numeric Water Quality Targets and Pollutant Sources

EPA regulations define loading, or assimilative capacity, as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 CFR Part 130.2(f)).

Using the D.O. water quality criterion of 5.0 mg/l (or 4.0 mg/l for periods of extreme low flow) and the 3.0 mg/l in the LWF reaches, a TMDL model analysis was performed through a critical summer period along with a winter period to determine the loading capacity for the watershed. The evaluation also considered a 0.5 mg/L addition to the targets to account for daily dissolved oxygen fluctuations. This was accomplished through a dynamic simulation aimed at meeting the dissolved oxygen target limit by varying source contributions, either point or nonpoint sources. In the case of the nonpoint source loads, the simulations reflect the effects of NPS loads on sediment oxygen demand. The final acceptable simulation represented the TMDL (and loading capacity of the waterbody).

The linkage between the nonpoint source loading model developed for the Flint Creek watershed and the instream dissolved oxygen simulations was achieved by identification of impacted and reference SOD values in the system. EPA has conducted studies to develop a database of measured sediment oxygen demand throughout Region IV. Within this database, representative values of sediment oxygen demand within stream segments were identified. Additionally, recent TMDL development on four watersheds within the southern portion of Georgia, and the Middle portions of Georgia identified unimpacted SOD levels in stream segments. For the purpose of this TMDL a “reference” SOD was identified as 1.30 gm/m^2/day.

Landuse Category	Area (acres)	Relative Distribution
Barren	94.7	0.72%
Cropland	884.1	6.77%
Forest	9,920.4	75.91%
Harvested Wood	116.6	0.89%
Pasture	1,970.0	15.07%
Strip Mining	0.0	0.00%
Urban Impervious	6.0	0.05%
Urban Pervious	1.1	0.01%
Wetlands	56.1	0.43%

Table 3-5. Land Use Distribution in Mill Creek Watershed

Within the Flint Creek watershed a reference watershed was identified (Mill Creek). This reach was not impaired relative to dissolved oxygen and organic enrichment and showed reduced areas of agricultural land use (Table 3-5). Applying the land use distribution associated with Mill Creek to the remaining Flint Creek watershed allowed the determination of natural loading conditions for each of the listed reaches. For this natural loading condition, a 1.30 gm/m2/day SOD value was assigned and the dissolved oxygen profile under critical conditions was developed for comparison with the impacted conditions. The TMDL for each reach was then determined as that percent reduction in load between the impacted condition and the natural condition that satisfied the water quality targets listed above throughout the year. Some reaches showed that under natural conditions the dissolved oxygen levels were above the target. Where model simulations showed that the natural conditions were below the target, the loads assigned that reach reflect natural conditions.

3.4 Data Availability and Analysis

A wide range of data and information were used to characterize the watershed and the instream conditions. The categories of data used include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify potential pollutant sources and their contribution, and in-stream water quality monitoring data.

The instream water quality data utilized in the TMDL development came from an intensive monitoring program initiated in a joint effort between the Geological Survey of Alabama (GSA) and the Alabama Department of Environmental Management (ADEM). The water quality data were collected for specific sites in the watershed between 1993 to 1998 for use in TMDL development and to document impacts and improvements in water quality that might result from the use of best management practices to control nonpoint source polluted water runoff. The data were collected in accordance with a 1992 monitoring plan developed by Flint Creek Watershed Project (FCWP) Technical Committee. Section 3.3.4 summarizes this data collection effort.

3.4.1. Watershed Characterization Data

Three types of spatial watershed information are utilized in this TMDL development. These are:

- Digital Elevation Data (DEM)
- MLRC Landuse Coverage
- National Hydrology Database Reach Network (NHD).

Figure 3-3 presents a spatial contour plot of the DEM data. This outlines the gradients seen in the system and highlights the low slope and grade of Flint Creek, and West Flint Creek especially in the lower reaches. This accounts for the significant degree of backwatering that occurs under low flow conditions and elevated lake levels.

Figure 2-2 presented the MLRC landuse distribution throughout the watershed with Table 3-3 outlining the percent breakdown by landuse. Figure 3-4 presents the NHD stream network within the Flint Creek Watershed. This data was utilized to provide the general connectivity and routing within the system for both the watershed and instream receiving water model.

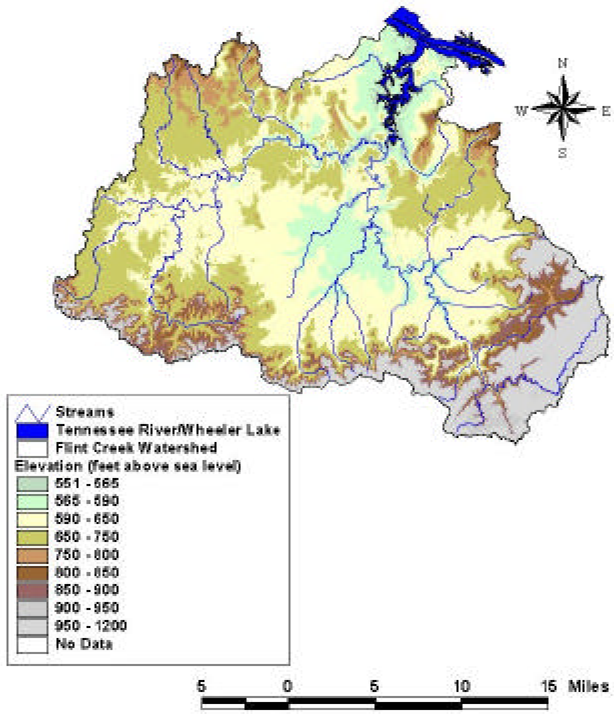

Figure 3-3. DEM Data

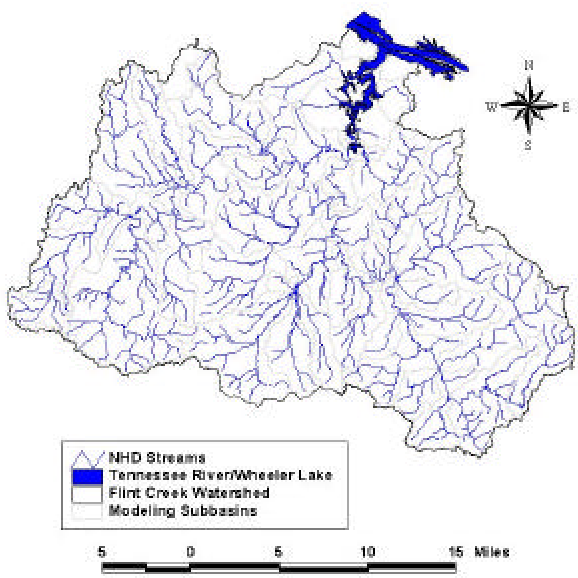

Figure 3-4. NHD Data

3.4.2. In-Stream Flow Data

There are two USGS flow gages with recent observation data in the Flint Creek watershed. Flow data from these gages were used to support flow analysis for the watershed. Table 3-6 shows the flow gaging stations used in this study and the corresponding period of record for each. These stations were the only stations with sufficient data to characterize the stream flow in the watershed. Figure 3-5 shows the location of the USGS flow gages used in TMDL development for the Flint Creek watershed.

Station	Stream Name	Drainage Area (square miles)	Start Date	End Date	Min (cfs)	Mean (cfs)	Max (cfs)
3577000	West Flint Creek near Oakville, AL	87.6	9/1/52	9/30/98	0	185	3980
3576500	Flint Creek near Falkville, AL	86.3	8/1/52	9/30/99	0	164	6260

Table 3-6. USGS Flow Gaging Stations

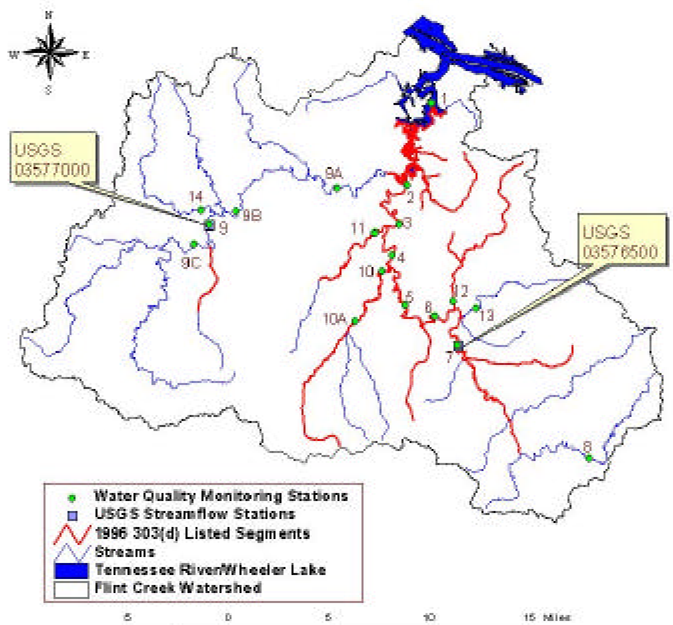

Figure 3-5. USGS Gaging Stations and Water Quality Monitoring Stations

3.4.3. Meteorological Data

Meteorological data are a critical component of the watershed model and the instream model. For the watershed and instream water quality model the following meteorological parameters are necessary, these are:

- Rainfall
- Air temperature
- Solar radiation
- Wind speed and direction
- Relative humidity
- Cloud cover

Long-term hourly data available from two National Climatic Data Center (NCDC) weather stations located near the watershed were used:

$ Haleyville
$ Huntsville WSO Airport

The Huntsville weather data was utilized for all watersheds except for subwatersheds 57 and 58, where the Haleyville precipitation data were applied.

3.4.4. In-Stream Water Quality

There are approximately 18 existing water quality stations in the Flint Creek watershed. ADEM provided water quality monitoring data for the 18 sampling stations from 1993 through 1998. Data from 13 of those stations located on the 9 segments listed for dissolved oxygen and organic enrichment were analyzed. Figure 3-5 presents the locations of the water quality stations in the Flint Creek watershed. Examination of the dissolved oxygen data from the 13 stations confirms that water quality criteria were violated in all 303(d)-listed stream reaches. The collection, preservation, and analysis of water samples were in accordance with approved quality assurance and quality control (QA/QC) plans and guidelines of the U.S. Environmental Protection Agency and ADEM (Chandler, 1999). The list of parameters analyzed for in the discrete sampling which relate to the DO/OE TMDL are:

- Dissolved oxygen (DO)
- 5-day Biochemical Oxygen Demand (BOD_5)
- Ammonia as Nitrogen (NH_3-N)
- Nitrate/Nitrite as N (NO_3-NO_2-N)
- Total Kejldahl Nitrogen (TKN)
- Total Phosphorus (TP)
- Ortho-Phosphorus (PO_4-P)
- Chlorophyll-a

In addition to the discrete monthly sampling events two continuous water quality monitors were installed in September of 1993 at surface water sites 7 and 9 with the station at site 9 being relocated in 1994 to avoid vandalism. These instruments collected continuous measurements of dissolved oxygen, temperature, conductivity, and pH from 1993 to 1998.

3.4.5. Point Source Discharge Data

For this TMDL only two point source discharges were considered, these are the Hartselle and Falkville discharges. Details on the discharges are presented in Section 3.2.2.

3.4.5. Special Studies

Various special studies were conducted within the Flint Creek watershed during the period 1993 to 1998, that were used in the development of the TMDL. These studies provided measurements of the following:

- Reaeration within Flint Creek
- Sediment Oxygen Demand within Flint Creek
- Ultimate Biochemical Oxygen Demand within Flint Creek

Reaeration

A special study was conducted on two reaches along Flint Creek to quantify the reaeration rate within the system (EPA 1996a). The studies utilized Rhodomine Dye tracer with non-radioactive krypton gas. The study quantified the level of reaeration on Flint Creek during the summer months.

Sediment Oxygen Demand

Sediment oxygen demand was measured at three stations along the Flint River as part of a community metabolism study conducted in June of 1996. The locations of the measurement stations are shown on Figure 3-6. The measured SOD values are presented in Table 3-7. The measured SOD values indicate a high level of oxygen demand within the substrate in relation to other typically less impacted areas.

Sediment Oxygen Demand Sampling Station	Corresponding GSA Site Location	Net Respiration (g O_2/m^3/day)	Average Water Column Depth (m)	Sediment Oxygen Demand (g O_2/m^2/day)
FC1	Site 7	2.89	0.6	2.3
FC3	Site 6	1.73	0.8	3.2
FC11	none (Flint below Crowdabout Cr.)	2.88	0.8	3.3
			Average:	2.9

Table 3-7. Measured SOD Values

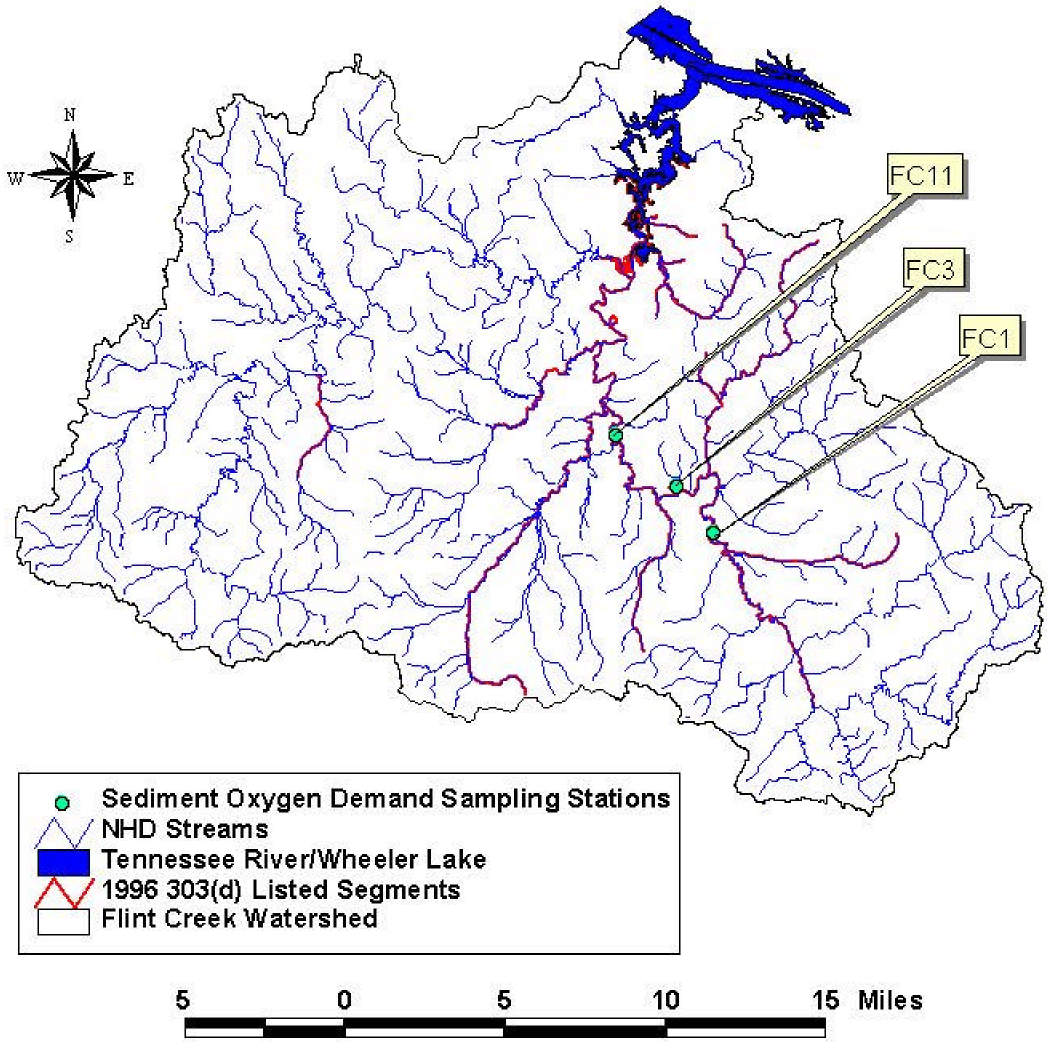

Figure 3-6. SOD Sampling Stations

Ultimate Biochemical Oxygen Demand

Ultimate Biochemical Oxygen Demand was measured at three stations along Flint Creek. The stations locations are shown on Figure 3-7. The $CBOD_u$, CBOD5, and f-ratios are presented in Table 3-8.

BOD-U Sampling Station	Corresponding GSA Site Location	CBOD-5	CBOD-U	Ratio
F6	Site 5	2.89	8.92	3.09
F4	Site 6	1.73	5.81	3.35
F3	none (Flint @ Shoal Ck.)	2.88	11.61	4.03

Table 3-8. Measured CBODU Values

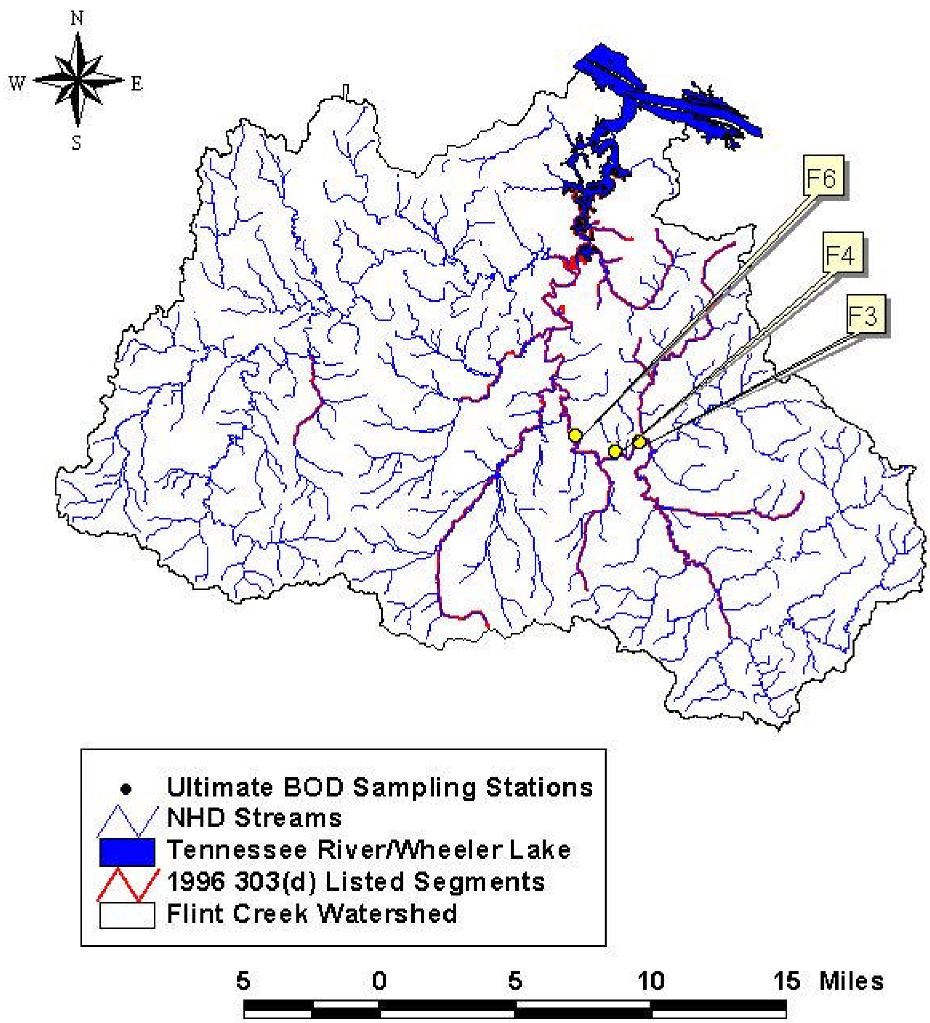

Figure 3-7. CBODU Sampling Stations

4.0 Model Development

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate the loading of organic material and nutrients, and the resulting in-stream response of dissolved oxygen are presented. For this TMDL a system of models was developed to allow the determination of the watershed loads to the listed reaches, the instream flow and transport within the listed reaches, and the instream response of critical water quality parameters. The system of models includes the following:

- Loading Simulation Program in C (LSPC) – to quantify the loads of organic material and nutrients to the listed reaches
- Environmental Fluid Dynamics Code (EFDC) – to simulate the flow and transport of material within the listed reaches.
- Water Quality Analysis and Simulation Program (WASP) – to simulate the instream response of critical water quality parameters to the watershed loads.

The following presents general descriptions of each of the models along with brief descriptions of the model calibrations and applications. A complete discussion of the development, calibration and application of the models is presented in the Draft Modeling Report.

4.1 Watershed Model – LSPC

For the determination of the watershed loads to the receiving waters hydrologic response and pollutant loading model calibrations must occur. The first is the calibration of the hydrologic response of the watershed to rainfall and background source flows. During periods of precipitation, the rainfall will govern hydrology and subsequent loads of organic material and nutrients. During dry periods, past events and their associated storage and background inflows will govern the system hydrology. In each case there is a subsequent load to the listed waters that must be carried forward to the instream modeling. Loads washed into the system will pass through and/or react during dry periods if the loads still remain in the water column. In addition, build up of organic material in the listed reaches from past high flow events can create increased sediment oxygen demand that exerts itself during low flow periods. In each case, the development of a TMDL that accounts for the nonpoint source impacts upon the system requires the quantification of the total load and it’s distribution.

4.1.1. Hydrology Model Selection, Set Up and Calibration

Based on the considerations described above, analysis of the monitoring data, review of the literature, and past modeling experience, the Loading Simulation Program C++ (LSPC) was used to represent the source-response linkage in the Flint Creek watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading from nonpoint and point sources found in the Flint Creek watershed and simulating in-stream processes. LSPC is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling. MDAS was developed by EPA Region 3 through mining TMDL applications in Region 3.

LSPC is a system designed to support TMDL development for areas impacted by nonpoint and point sources. The most critical component of LSPC to TMDL development is the dynamic watershed model, because it provides the linkage between source contributions, in-stream response during routing of flows, and delivery of loads to receiving streams. The comprehensive watershed model is used to simulate watershed hydrology and pollutant transport as well as stream hydraulics and in-stream water quality. It is capable of simulating flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and waterbodies. LSPC was configured for the Flint Creek watershed to simulate the watershed as a series of the hydrologically connected subwatersheds which contribute loads to various lengths of the listed reaches. Configuration of the model involved subdivision of the Flint Creek watershed into modeling units and continuous simulation of flow and water quality for these units using meteorological, land use, and stream data. The only pollutants simulated are nutrients and biochemical oxygen demand. This section describes the configuration process and key components of the model in greater detail.

To represent watershed loadings and resulting concentrations of nutrients and biochemical oxygen demand to the stream segments, the watershed was divided into 58 subwatersheds. These subwatersheds represent hydrologic boundaries. The division was based on elevation data (7.5 minute Digital Elevation Model [DEM] from USGS), stream connectivity (from the National Hydrography Dataset stream coverage), and the locations of monitoring stations.

The hydrology of the LSPC model was calibrated for water year 1998 at USGS gage 3577000 on West Flint Creek. The hydrology calibration was performed prior to water quality calibration and involved adjustment of the model parameters used to represent the hydrologic cycle until acceptable agreement was achieved between simulated flows and historic stream flow data measured at gage 3577000 for the same period of time. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. Modeled flow was also compared to observed flow data at gage 3576500 on Flint Creek for validation of the calibration at gage 3577000. The model output was further validated at stations 3577000 and 3576500 for the 7-year period of

1992 through 1998. Modeled flow was also compared to flow observations available at each of the water quality stations. The hydrological calibration and validation plots are presented in the Draft Modeling Report.

4.1.2. Water Quality Model Selection, Set Up and Calibration

A dynamic computer model was selected for nutrients and CBOD5 analysis in order to: a) simulate the time varying nature of deposition on land surfaces and transport to receiving waters; and b) incorporate seasonal effects on the production and fate of nutrients and CBOD.

In addition to LSPC, the WCS was used to display, analyze, and compile available information to support water quality model simulations. Results of the WCS characterization are input to a spreadsheet developed by Tetra Tech, Inc. The spreadsheet is used to estimate modeling parameters associated with nutrients and CBOD5 buildup and washoff loading rates. The spreadsheet is also used to estimate direct sources of loading to water bodies from leaking/failing septic systems and animals having access to streams, in particular grazing beef cattle. Information from the WCS and spreadsheet tool have been used as initial input for variables in the LSPC model.

For modeling purposes, the nutrient and CBOD5 sources are represented by the following components:

- runoff loads from land uses (build-up and washoff due to runoff)
- direct source loads from cattle in the streams and failing septic systems

Typically, nonpoint sources are characterized by buildup and washoff processes: they contribute material to the land surface, where they accumulate and are available for runoff during storm events. These nonpoint sources can be represented in the model as land-based runoff from the land use categories to account for their contribution to form loading within the watersheds. Accumulation rates (number per acre per day) can be calculated for each land use based on all sources contributing nutrients and CBOD5 to the surface of the land use. For this study, where specific sources were identified as contributing to a land use, accumulation rates were calculated. For example, grazing livestock and wildlife are specific sources contributing to land uses within the watershed. The land uses that experience accumulation due to livestock and wildlife include:

- ❑ Cropland (livestock and wildlife)
- ❑ Forest (wildlife)
- ❑ Pasture (livestock and wildlife)
- ❑ Wetlands (wildlife)

Accumulation rates can be derived using the distribution of animals by land use and using typical production rates for different animal types (Table 4-1). The nutrient and CBOD5 accumulation rate for pasturelands is the sum of the individual accumulation rates due to contributions from grazing livestock, the application of manure (dairy cows and chickens), and wildlife. The nutrient and CBOD5 accumulation rate for cropland is the sum of the individual accumulation rates due to contributions from grazing livestock, the application of manure (hogs and chickens), and wildlife.

Animal	Fecal Coliform Production Rate	Reference
Cattle	1.0×10^{11} counts/day	ASAE, 1998
Chickens	1.4×10^{8} counts/day	ASAE, 1998
Hogs	1.1×10^{10} counts/day	ASAE, 1998
Deer	5×10^{8} counts/day	Linear interpolation; Metcalf & Eddy, 1991

Table 4-1. Animal Production Rates

The estimated number of livestock animals in the Flint Creek watershed is discussed in Section 3.2.3. For modeling purposes, it was assumed that dairy cows are confined most of the time and that their waste is applied to pasture land. Beef cattle were assumed to have access to streams and were considered to be a direct nonpoint source of nutrients to the stream reaches. Chicken waste was assumed to be applied to pasture and hog waste was assumed applied to cropland.

Literature values for typical nutrient and CBOD5 accumulation rates were used for the urban land uses. The literature value used for urban land uses is the median default value for commercial land (Horner, 1992). The value used for barren and strip mining land uses was half of the urban value. The value used for nutrient and CBOD5 accumulation rates on the harvested wood land use was the same value as forest.

The LSPC model is a build-up and wash-off model that represents the pollutant by accumulating the pollutant over time, storing the pollutant to some maximum limit, and then transporting the pollutant through overland flow to the stream. The model represents these processes with an accumulation rate (ACQOP) and the storage limit (SQOLIM). The nutrient/CBOD5 spreadsheet calculates both of these values by using the livestock numbers and manure application rates, which come from literature values and the WCS data. WSQOP is defined as the rate of surface runoff (inches per hour) that results in 90 percent washoff in one hour. The lower the value, the more easily washoff occurs. This parameter is user-defined and was determined for each land use by EPA recommended ranges. The ACQOP and SQOLIM can be varied monthly or be a constant through the simulation. If specific data such as timing of manure applications, livestock rotations, and crop rotations are known, these rates can be calculated monthly. For the Flint Creek watershed modeling, the rates were input as constant values. There does not appear to be a clear rotation schedule of cattle and crops in the watershed. It was assumed that hog manure was applied to row crops year round.

Wildlife is another potential source of nutrients and CBOD5 loading to receiving waterbodies. For modeling purposes, the deer population is assumed to represent the wildlife contribution, since population data for other wildlife species in the watershed was not readily available. It is assumed that deer habitat within the watershed includes forest, cropland, pasture, and wetlands. Typical estimates for the distribution of white-tailed deer within the region were provided by the Alabama Department of Conservation, Division of Wildlife and Freshwater Fisheries (2000). The provided density (deer per square mile) was applied to deer habitat areas within the watershed to estimate population counts by subwatershed. The Flint Creek watershed typically has 15 or less deer per square mile. An average density of 7.5 deer per square mile was applied to forest, pasture, and cropland while a density of 15 deer per square mile was applied to wetland areas.

Cattle depositing manure directly into stream reaches represent a direct nonpoint source of nutrients and CBOD5. As stated earlier, it was assumed that only beef cattle have access to the stream reaches. It is assumed that dairy cows are mostly confined and that their waste is applied to pasture. The number of cattle producing and depositing waste in streams in the watershed at any give time were estimated. The percentage of cattle adjacent and non-adjacent to the stream reaches was determined for each subwatershed based on information provided in the *Flint Creek Watershed Project: Flint Creek Pollutant Loading Estimates* (Morgan County Soil and Water Conservation District 1995). It was assumed that 10 percent of the beef cattle have access to the stream, 3 percent are actually in the stream, and 1 percent of the cattle are depositing waste directly in the stream. The cattle were simulated in the model as direct sources of nutrients and CBOD5 loads, with a representative flow rate (cubic feet per second) and load (counts per hour). The representative load was calculated based on the number of cows in the stream and the production rate for cows. The flow was estimated based on the number of cows in the stream, the manure production rate of cows (ASAE 1998) and the approximate density of cow manure.

Failing septic systems represent a nonpoint source that can contribute nutrients and CBOD5 to receiving waterbodies through surface or subsurface malfunctions. The estimated number of septic systems and the percent failure rate were provided by the SWCA Database. To provide for a margin of safety accounting for the uncertainty of the number, location, and behavior (e.g., surface vs. subsurface breakouts; proximity to stream) of the failing systems, failing septic systems are represented in the model as direct sources of nutrients and CBOD5 to the stream reaches. Contributions from failing septic system discharges are included in the model with a representative flow and concentration, which were quantified based on the following information:

$ Number of failing septic systems in each subwatershed.
$ Estimated population served by the septic systems (an average of 2.5 people per household, obtained from 2000 Bureau of the Census data).
$ An average daily discharge of 70 gallons/person/day (Horsley & Witten 1996).
$ Septic effluent concentration of 220 mg/l of CBOD5, 15 mg/L organic nitrogen, 25 mg/L ammonia, 3 mg/L organic phosphorus, and 5 mg/L inorganic phosphorus (Metcalf and Eddy, 1991).

Following hydrology calibration, the water quality constituents were calibrated. Modeled versus observed in-stream concentrations for all of the nutrient species along with the

CBOD5 were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting water quality parameters within a reasonable range. The parameters that were adjusted to obtain a calibrated model were the build-up and washoff of nutrients and CBOD5 from the land use coverages and the direct loads such as cattle in the streams and the failing septic systems.

The approach taken to calibrate water quality focused on matching trends identified during the water quality analysis. Daily average in-stream concentrations from the model were compared directly to observed data. Observed nutrient and CBOD5 data were obtained from ADEM for 1993 through 1998. The objective was to best simulate low flow, mean flow, and storm peaks at representative water quality monitoring stations. The model was calibrated at all water quality stations with observation data during the chosen calibration period. These stations were typically ADEM monitoring stations (See Figure 3-5).

The time period of the model simulation was from 1992 through 1998. This time period was selected based on the availability and relevance of the observed data to the current conditions in the watershed. The model was calibrated for the year 1997, which represented both high and low flow periods. For each water quality station, model results were plotted against the respective observed data to assess the model's response to spatial variation of loading sources. The results of the water quality calibrations for each of the listed pollutants are presented in the Draft Modeling Report.

4.2 Receiving Water Models – EFDC and WASP

Section 4.1 presented the watershed model utilized to develop the time dependant overland flows and pollutant concentrations to be input to the receiving water models. The receiving water models take the pollutant loads from the watershed model (nonpoint source loads) along with available information on the point source loads to the system, and provide for the transport and transformation of the material as it moves through the system. In the case of nutrients and organic material, the models provide for the oxidation, nitrification, uptake through photosynthesis, and other processes, and simulates the instream dissolved oxygen concentrations. Additionally, the instream models provide for the balance in the water column between oxygen depletion due to the processes described above, sediment oxygen demand, and reaeration across the water surface. These processes act on the water as it moves through the system under the simulated flow and transport.

4.2.1. Hydrodynamic Model Selection, Set Up and Calibration (EFDC)

In order to simulate the flow and transport within the listed, reaches a hydrodynamic model which simulates the flow, velocity and transport was developed. The EFDC model was utilized with a 2-dimensional simulation grid within the lower reaches of Flint Creek the primary backwater area of Wheeler Lake. Within the upper portions of the Flint Creek and West Flint Creek a 1-dimensional application of the EFDC hydrodynamic model was applied.

The Environmental Fluid Dynamics Code (EFDC) is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands and near shore to shelf scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software. The EFDC code has been extensively tested and documented.

Within the EFDC modeling package, solutions for flow and transport can be made on multiple scales i.e. 1-D or 2-D. These models solve the 1-D/2-D continuity, momentum, and transport equations. The models use the efficient numerical solution routines within the more general 2-D/3-D EFDC hydrodynamic model, as well as the transport and meteorological forcing functions. In addition, it allows for specification of time variable water surface elevation at the downstream boundary, i.e. allowing a time dependant Lake Wheeler water surface elevation as the downstream boundary of the Flint Creek simulations. Specific details on the model equations, solution techniques and assumptions can be found in Hamrick (1996).

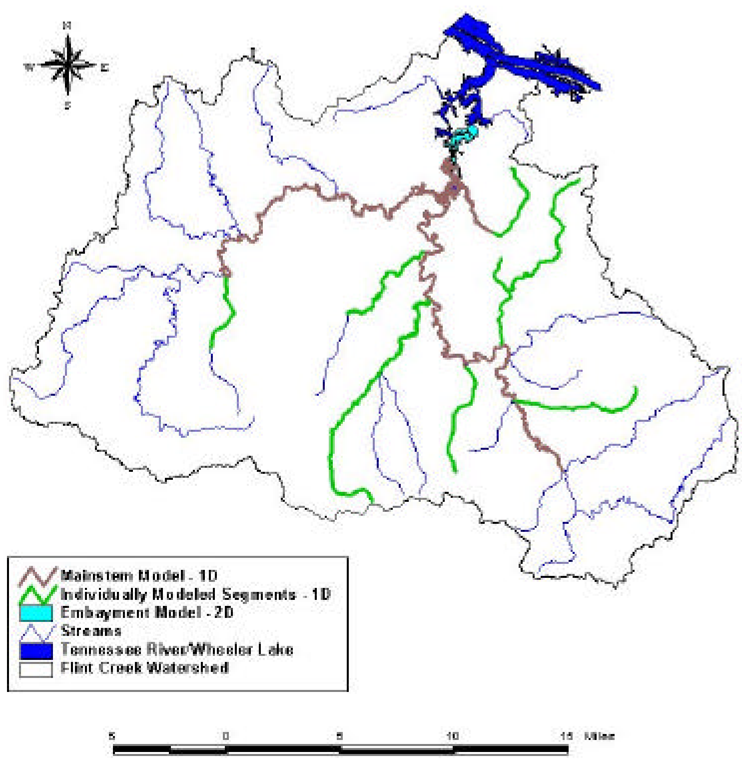

Figure 4-1. Extents of Instream Model Grid

Inputs to the EFDC Flint Creek and West Flint Creek hydrodynamic model include the following:

- Model grid and geometry
- Lake Wheeler water surface elevation
- Flows at headwaters and distributed flows from watershed

The model grid was developed based upon the shorelines from USGS Topographic Maps, measured cross-sectional information from ADEM, elevation data (7.5 minute Digital Elevation Model [DEM] from USGS), and stream connectivity (from the National Hydrography Dataset stream coverage). Figure 4-1 presents the extents of the EFDC model grid with the 2-D and 1-D portions of the grid identified. The grid covers all of the listed reaches along with those stream sections required to provide overall connectivity between the listed segments, Flint Creek, West Flint Creek, and the other simulated tributaries, Shoal Creek, Town Creek, No Business Creek, McDaniel Creek, Village Branch, Mack Creek, and Robinson Creek.

The lower boundary of the model grid is at the mouth of Flint Creek to Lake Wheeler. The lake level fluctuates seasonally based upon prescribed lake management practices. The lake levels fluctuate between 550 and 557 feet NGVD with low lake levels from November through March and high lake levels from March through October. The degree of backwater in the system under critical summer periods when the lake level is maintained near 557 feet can be critical. During this period backwater in the system reaches over 20 miles upstream.

Flow inputs to the system come at headwaters of the reaches within the model, as well as distributed flows representing tributary inflow and direct overland flow. Headwater flows come from the LSPC model output at the base of subwatersheds that discharge to the headwaters of the various listed reaches. Flows from non-listed tributaries within the Flint Creek watershed that merge with listed reaches come from the LSPC model output at the base of the unlisted subwatershed. Finally, subwatersheds with listed reaches within them are provided flow as that coming directly from the land portion of LSPC prior to routing to the subwatershed reach.

Calibration of the hydrodynamic model was limited to comparison of measured flows at the two USGS gaging stations along the Flint Creek and West Flint Creek. Details of the model calibration are presented in the Draft modeling report referenced earlier.

4.2.2. Water Quality Model Selection, Set Up and Calibration (WASP)

In order to simulate the temporal and spatial dissolved oxygen concentrations, a water quality model must be utilized which simulates the full eutrophication kinetics including phosphorus and nitrogen cycling, oxidation of organic material, sediment oxygen demand, and reaeration across the water surface. The WASP model was utilized with a 2-dimensional simulation grid within the lower reaches of Flint Creek the primary backwater area of Wheeler Lake. Within the upper portions of the Flint Creek and West Flint Creek a 1-dimensional application of the WASP model was applied.

For simulation of the water quality within the LA River, the EFDC model was externally linked to the Water Quality Analysis Simulation Program (WASP5) through a hydrodynamic forcing file that contains the flows, volumes, and exchange coefficients between adjacent cells. WASP5, an enhancement of the original WASP model (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988), a dynamic compartment model program for aquatic systems, including both the water column and the underlying benthos. The time varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program.

Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP5 permits the modeler to structure one, two, and three-dimensional models; allows the specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions; and permits tailored structuring of the kinetic processes, all within the larger modeling framework without having to write or rewrite large sections of computer code.

For the Flint Creek watershed simulations, the WASP model was run under full eutrophication kinetics with the following state variables simulated:

- Dissolved oxygen (DO)
- Ultimate Carbonaceous Biochemical Oxygen Demand (CBODU)
- Ammonia as Nitrogen (NH_3-N)
- Nitrate/Nitrite as N (NO_3-NO_2-N)
- Organic Nitrogen (ON)
- Phosphorus (TP)
- Ortho-Phosphorus (PO_4-P)
- Chlorophyll-a

In order to perform the full eutrophication simulations the following general input conditions were required.

- Boundary flows and concentrations for all 8 state variables where flow enters the model (see Section 4.2.1 under hydrodynamic flow inputs)
- Spatial distribution of Sediment Oxygen Demand
- Meteorological forcings
- Model input coefficients

Boundary flows and concentrations came from the LSPC simulations described in Section 4.1.2. The boundary conditions utilized in the simulations are presented in the Draft modeling report.

As described in Section 3.4.5 sediment oxygen demand measurements were taken at various locations throughout the system. These values were utilized to develop the sediment oxygen demand throughout the system with average values used in the model.

Meteorological data used in the WASP model came from the Huntsville, AL weather station data described in Section 3.0. For the WASP model hourly weather data is utilized for the inputs.

The WASP model input coefficients reflect the best available literature values, and where available (i.e. CBOD decay rate) site-specific values are utilized. The best fit between the WASP model simulations and the measured data is obtained by variation of critical parameters within the range of acceptable literature values. Where site specific measured values are used not adjustment of those coefficients is made. A full detailed discussion of the WASP model calibration is presented in the Draft Modeling Report.

4.3 Critical Conditions

Data analysis shows that the critical condition is the summer low flow periods. The dissolved oxygen conditions within the Flint Creek watershed corresponds to summer periods of low flow, where Lake Wheeler levels create significant backwatering up the Flint Creek and the West Flint Creek. For the purpose of this TMDL a low flow year with high temperatures was utilized for the purpose of determining the TMDL to represent the worst case conditions.. The simulations were performed with time dependant daily fluctuations of Lake Wheeler water surface elevation, simulated inflows from the LSPC model with simulated concentrations of the eight state variables, measured meteorological conditions, and measured sediment oxygen demand.

4.4 Margin of Safety (MOS)

There are two methods for incorporating a MOS in the analysis: a) by implicitly incorporating the MOS using conservative model assumptions to develop allocations; or b) by explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations. An implicit MOS was incorporated in this TMDL. This TMDL used the worst case conditions of low flow year with high temperatures. Also this implicit MOS included conservative modeling assumptions and a continuous simulation that incorporates a range of meteorological events. Conservative modeling assumptions used include: septic systems discharging directly into the streams, conservative estimates of in-stream decay, point sources discharging at permitted flows, and all land areas considered to be connected directly to streams. Nutrient and organic material loss on the land surface is not computed in the model. Therefore, the loads delivered to the model do not account for this decay and are a conservative.

4.5 Seasonal Variation

Seasonal variation is considered in the development of the TMDL because the allocation runs are performed over an entire calendar year. The model simulates the response of the dissolved oxygen under various hydrologic, meteorological and loading conditions, thus fully evaluating the potential seasonal variations. In the months of November through March, when the LWS classification goes from a 3.0 mg/L to a 5.0 mg/L (3.5 mg/L to 5.5

mg/L in terms of model simulations), the allocations are evaluated based upon meeting a 5.5 mg/L condition throughout the system.

5.0 TMDL Development

This section presents the TMDLs developed for nutrients and organic enrichment for the Flint Creek watershed (including Flint Creek, Shoal Creek, Crowdabout Creek, No Business Creek, Village Branch, Town Branch, Robinson Creek, McDaniel Creek, and Mack Creek). The TMDLs are presented as annual average lbs per year of CBOD, NBOD, Total Nitrogen and Total Phosphorus. Model output for 1993 was used to determine the TMDLs and allocation scenarios because the modeled water quality during 1993 represented critical conditions during the modeling period. There were additional years that represented critical conditions in the watershed, but were not chosen because of extreme weather conditions (i.e., tropical storms, El Niño, hurricanes, and droughts). The year 1993 was chosen to determine TMDLs and allocation scenarios because it was representative of more typical weather conditions, but still contained significant low flow periods.

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality criteria, in this case Alabama's water quality criteria for aquatic life. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly of explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$TMDL = WLAs + LAs + MOS$$

In order to develop the TMDL presented herein, the following approach was taken:

- Define TMDL endpoints
- Simulate baseline conditions
- Determine the TMDL and source allocations

5.1 TMDL Endpoints

TMDL endpoints represent the in-stream water quality targets used in quantifying TMDLs and their individual components. The spatially and temporally varying instream dissolved oxygen concentration was selected as the TMDL endpoint for the organic enrichment and nutrient TMDLs within the Flint Creek watershed. For the critical summer period when extreme low flow conditions occur, a 4.0 mg/L target in the portions of the listed reaches classified as Fish and Wildlife and Public Water Supply was used, while in those reaches listed as Limited Warmwater Fishing a 3.0 mg/L target was used. During other periods, and in the non-summer months a 5.0 mg/L target was utilized. In all cases the TMDL targets are increased by 0.5 mg/L in order to account for diurnal fluctuations utilizing a model projection of daily average dissolved oxygen.

5.2 Baseline Conditions

The calibrated model provided the basis for performing the allocation analysis. The first step in the analysis involved simulation of baseline conditions. Baseline conditions represent existing nonpoint source loading conditions and permitted point source discharge conditions. The existing load for the listed segment is represented as the sum of the daily discharge load of the direct nonpoint sources, the point sources loads, and the daily load indirectly going to surface waters from all land uses (e.g., surface runoff) for 1993. The baseline conditions allow for an evaluation of in-stream water quality under critical conditions.

The model was run for baseline conditions from January 1, 1993 through December 31, 1993. Predicted in-stream concentrations of dissolved oxygen for the listed waterbodies and their tributaries were compared directly to the TMDL endpoints. This comparison allowed evaluation of the expected magnitude and frequency of exceedance under a range of hydrologic and environmental conditions, including dry periods, wet periods, and more typical periods.

5.3 TMDLs and Source Allocations

A top-down methodology was followed to develop the TMDLs and allocate loads to sources. Impaired headwaters were first analyzed because their impact frequently had an effect on down-stream water quality. Loading contributions were reduced from applicable sources for these waterbodies and TMDLs were developed.

Evaluation of the net impact of the point sources on dissolved oxygen was first evaluated. The results showed that the impacts associated with the point source loads is less than 0.1 mg/L and therefore insignificant in relation to other impacts.

During critical low flow periods no direct association between nonpoint source loads and instream pollutant concentrations can be made. In general nonpoint source impacts are associated with prior deposition of organic material washed into the system during winter storm periods. This excess organic material then creates increased sediment oxygen demand during critical low flow periods. Allocation to the nonpoint sources therefore requires development of links between the nonpoint source loads and the level of sediment oxygen demand within the system. Under load allocations the sediment oxygen demand is reduced in order to meet water quality standards and then the associated nonpoint load reductions determined based upon the SOD/load relations. Detailed discussions of the linkage between SOD and the NPS loads are presented in Section 3.3 and the Draft Modeling Report.

5.4 Wasteload Allocations

Significant permitted facilities that exist in the watershed include two dischargers. The two facilities are located on Shoal Creek and Flint Creek. For TMDL evaluations, the two municipal facilities were assumed to be discharging at their permitted limits.

Simulations of the 1993 year with and without the point source discharges identified a net impact less than 0.1 mg/L. Based upon this level of impact the point sources were not considered to be major contributing sources that caused or contributed to the water quality problem. No reductions were considered from point sources.

5.5 Load Allocations

Significant nonpoint source loads of organic material and nutrients within the Flint Creek watershed are associated with washoff from agricultural land uses (cropland and pasture). Loads associated with direct discharge from cattle in streams and failing septic systems are insignificant. Therefore all load allocation reductions come from cropland and pasture runoff.

5.6 TMDL Results

The Table 1-2 presents a summary of the existing loads and the TMDL of CBOD, NBOD, Total Phosphorus, and Total Nitrogen to each of the listed reaches. The Table presents the existing load conditions by listed reach, the Total Maximum Daily Loads for each listed reach, and the percent reductions for each.

The reductions were based upon reductions needed in sediment oxygen demand in order to meet water quality criteria. The loads were then determined based upon relationships developed between loads and sediment oxygen demand. The details of the development of this relationship are presented in the Draft Modeling Report. In summary, a reference watershed within the Flint Creek watershed was chosen and the annual average load/area for organics and nutrients determined based upon simulations from 1993 through 1998. Utilizing the EPA database on sediment oxygen demand, a representative unimpacted SOD value of 1.3 gm/m2/day was chosen. The measured SOD values within the Flint Creek watershed, along with the annual average load within those areas were calculated. Utilizing the reductions in SOD necessary to achieve water quality standards along, along with the NPS Load/SOD relationship, the net reductions in nonpoint source loads for each listed reach were determined.

6.0 TMDL Implementation

6.1 Non-Point Source Approach

The Flint Creek watershed is impaired by nonpoint sources from land use runoff. For 303(d) listed waters impaired solely or primarily by nonpoint source (NPS) pollutants, necessary reductions will be sought during TMDL implementation using a phased approach. Voluntary, incentive-based mechanisms will be used to implement NPS management measures in order to assure that measurable reductions in pollutant loadings can be achieved for the targeted impaired water. Cooperation and active participation by the general public and various industry, business, and environmental groups is critical to successful implementation of TMDLs. Local citizen-led and implemented management measures offer the most efficient and comprehensive avenue for reduction of loading rates from nonpoint sources. Therefore, TMDL implementation activities will be coordinated through interaction with local entities in conjunction with Clean Water Partnership efforts.

The primary TMDL implementation mechanism used will employ concurrent education and outreach, training, technology transfer, and technical assistance with incentive-based pollutant management measures. The State and local governments will take the primary lead in the TMDL implementation. Options include the following. The ADEM Office of Education and Outreach (OEO) will assist in the implementation of TMDLs in cooperation with public and private stakeholders. Planning and oversight will be provided by or coordinated with the Alabama Department of Environmental Management's (ADEM) Section 319 nonpoint source grant program in conjunction with other local, state, and federal resource management and protection programs and authorities. The CWA Section 319 grant program may provide limited funding to specifically ascertain NPS pollution sources and causes, identify and coordinate management programs and resources, present education and outreach opportunities, promote pollution prevention, and implement needed management measures to restore impaired waters.

Depending on the pollutant of concern, resources for corrective actions may be provided, as applicable, by the Alabama Cooperative Extension System (education and outreach); the USDA-Natural Resources Conservation Service (NRCS) (technical assistance) and Farm Services Agency (FSA) (federal cost-share funding); and the Alabama Soil and Water Conservation Committee (state agricultural cost share funding and management measure implementation assistance) through local Soil and Water Conservation Districts, or Resource Conservation and Development Councils (funding, project implementation, and coordination). Additional assistance from such agencies as the Alabama Department of Public Health (septic systems), Alabama Department of Agriculture and Industries, and the Alabama Department of Industrial Relations and Dept of Interior - Office of Surface Mining (abandoned minelands), Natural Heritage Program and US Fish and Wildlife Service (threatened and endangered species), may also provide practical TMDL implementation delivery systems, programs, and information. Land use and urban sprawl issues will be addressed through the Nonpoint Education Source for Municipal Officials

(NEMO) outreach program. Memorandums of Agreement (MOAs) may be used as a tool to formally define roles and responsibilities.

Additional public/private assistance is available through the Alabama Clean Water Partnership Program (CWP). The CWP program uses a local citizen-based environmental protection approach to coordinate efforts to restore and protect the state's resources in accordance with the goals of the Clean Water Act. Interaction with the state or river basin specific CWP will facilitate TMDL implementation by providing improved and timely communication and information exchange between community-based groups, units of government, industry, special interest groups, and individuals. The CWP can assist local entities to plan, develop, and coordinate restoration strategies that holistically meet multiple needs, eliminate duplication of efforts, and allow for effective and efficient use of available resources to restore the impaired waterbody or watershed.

Other mechanisms that are available and may be used during implementation of this TMDL include local regulations or ordinances related to zoning, land use, or storm water runoff controls. Local governments can provide funding assistance through general revenues, bond issuance, special taxes, utility fees, and impact fees. If applicable, reductions from point sources will be addressed by the NPDES permit program. The Alabama Water Pollution Control Act empowers ADEM to monitor water quality, issue permits, conduct inspections, and pursue enforcement of discharge activities and conditions that threaten water quality. In addition to traditional "end-of-pipe" discharges, the ADEM NPDES permit program addresses animal feeding operations and land application of animal wastes. For certain water quality improvement projects, the State Clean Water Revolving Fund (SRF) can provide low interest loans to local governments.

Long-term physical, chemical, and biological improvements in water quality will be used to measure TMDL implementation success. As may be indicated by further evaluation of stream water quality, the effectiveness of implemented management measures may necessitate revisions of this TMDL. The ADEM will continue to monitor water quality according to the rotational river basin monitoring schedule as allowed by resources. In addition, assessments may include local citizen-volunteer monitoring through the Alabama Water Watch Program and/or data collected by agencies, universities, or other entities using standardized monitoring and assessment methodologies. Core management measures will include, but not be limited to water quality improvements and designated use support, preserving and enhancing public health, enhancing ecosystems, pollution prevention and load reductions, implementation of NPS controls, and public awareness and attitude/behavior changes.

6.2 Point Source Approach

Point source reductions are not significant and are not important or necessary to meet the TMDLs for the Flint Creek watershed.

7.0 Follow Up Monitoring

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, the ADEM water quality resources are concentrated in one of the basin groups. One goal is to continue to monitor §303(d) listed waters. This monitoring will occur in each basin according to the schedule in Table 7-1. The Flint Creek watershed is located in the Tennessee River basin.

River Basin Group	Scheduled Year
Cahaba / Black Warrior	2002
Tennessee	2003
Choctawhatchee / Chipola / Perdido-Escambia / Chattahoochee	2004
Tallapoosa / Alabama / Coosa	2005
Escatawpa / Upper Tombigbee / Lower Tombigbee / Mobile	2006

Table 7-1. Monitoring schedule for Alabama River Basins

Monitoring will help further characterize water quality conditions resulting from the implementation of best management practices in the watershed.

8.0 Public Participation

A thirty-day public notice will be provided for this TMDL. During this time, copies of this TMDL will be available upon request, and the public will be invited to provide comments on the TMDL.

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